AUTOMATON

OR

THE FUTURE OF THE MECHANICAL MAN

TO-DAY AND TO-MORROW

For the Contents of this Series see the end of the Book

AUTOMATON

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THE FUTURE OF THE MECHANICAL MAN

BY

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OR

THE FUTURE OF THE MECHANICAL MAN

EARLY in the nineteenth century, when the possibilities of invention and the application of science to industry began to be generally realized, it was accepted as almost self-evident that a time must come when all the material needs of man would be satisfied by machines requiring nothing but supervision and occasional repair Hymns of praise to the coming liberation of man from the curse of Adam were sung. Visions of a life of ample leisure for all filled the minds of men. The fact that the design and direction of the marvellous technical apparatus which was to free the mass from labour, would call for the service of a small, very highly trained, and very hard-worked class of scientists and engineers was, perhaps, somewhat neglected, together with the question as to what incentive there would be to belong to this class.

We have travelled far since those days. The multiplication both of men and of

wants has kept pace with our powers of feeding the first and fulfilling the second. We work nearly as long hours as ever, and far harder.

It is the purpose of this essay to review the situation in the light of our present-day ideas, or some of them. One of the most important of these is that most clearly stated by Spengler, namely, that we should think in terms of civilizations, and not of civilization. We are to disabuse our minds of the nineteenth-century idea of human progress, the vision of ourselves as the heirs of all the ages, at last emancipated from the thrall of past superstitions, and about to enter, by virtue of science, universal education, and an outlook finally divested of all irrationality, upon a gradual ascent to limitless liberty, happiness, and power. We see ourselves now as members of a particular civilization, one of many which this old Earth has seen grow up, and flourish. The active, creative life of the others has left them. A civilization is of the nature of an organism, the cells of which are the human individuals which, generation after generation, are born, fulfil their functions under the general organic control of the spirit of the civilization, and die, just as do the cells of our own bodies. They

are short lived in comparison with the organism of which they form part. But it, too, is born with the impulse to grow and develop in a certain way inherent in it from birth. It develops gradually its powers and peculiar individuality, reaches maturity, and declines to senility. This life course, though it may be interrupted by accidents, is settled, as regards its nature and duration, by the species "human civilization", to which the organism belongs It may well be that successive civilizations represent an organic advance. But it is hardly more sensible to assume that our civilization, which was born about the year A.D. 1000, is immortal and destined to limitless progress, than to assume the same of an individual human creature.

Our Western civilization has passed through stages similar, in kind and duration, to those which all other civilizations known to us have passed through. Like them, it developed its religion, its aristocracies, its forms of government; and these have already decayed almost completely to a rationalistic democracy, which itself is visibly and rapidly making way for a system of autocracies. All the many-sided instinctive creative impulses which enriched the early development of our Western world are fading away,

with one exception. A civilization may thus be compared to a powerful, first-rate individual, with a strong, many sided personality. In his youth, his impulses lead to the most varied activities, and suggest all manner of possibilities. As he matures, a ruling passion, a single aim in life develops, and other interests are subordinated to it. The ruling passion of our maturity is the conquest of power over the material world. Compared with the creative energy we have infused into that, all our other activities have, as civilizations go, been quite second-rate. Our religion, our art, our law were all derivative adaptations to our needs. Our philosophy, when it is our own, is merely, like our theology, a reflection of our dominant passion. That passion, which seems to us so inevitable, so magnificent, would have been almost incomprehensible, or at any rate, repulsive, to an ancient Chinese, Indian, or Greek. The Egyptians or Arabians might have felt, perhaps, a little more sympathy for it.

It is, of course, essential to any civilization to attain a measure of control over the forces of nature. Comfort, leisure, art, government, food supply for a dense population, all involve a certain mastery of material conditions. But this mastery

has always, in the past, been regarded as a means to an end, and not as an end in itself. Other religious systems have felt the need for a cosmogony, an account of the origin of the visible world, but the Creator was not worshipped as the supreme god, who had retained complete control over his creation, and was consequently omnipotent. We, on the other hand, set in the forefront of our creed God, the Father Almighty, Maker of Heaven and Earth, the Great Artificer. Our most recent gospel merely substitutes for this the hope and inspiration that we ourselves, incorporating the Life Force, will eventually attain to mastery over matter, and thus become the God of our early imaginations. To us the visible universe, ourselves included, is one grand invention of a Super-Edison. Out of a chaos of matter and energy a marvellous and infinitely complicated machine was created. Or, as the moderns teach, the Life Force found inorganic nature endowed with certain physical laws, and has striven continually, from the earliest beginnings of life, to attain to complete mastery over matter. There are moments when it appears almost incredible to a humble-minded engineer that his particular type

of activity should have been selected for elevation to Divine rank.

Automaton.—From the dawn of our civilization down to the last phases of *Back to Methuselah* our poets and writers have embodied our aspirations in legends of man-made automata. No sooner had we developed the simplest forms of self-moving mechanism, than we began making automatic men and animals. Early clocks, such as that at Strasbourg, are examples. The legend continued. Frankenstein and his "monster" enjoyed a great vogue in the eighteenth century. Recent examples are the Robot play and the film "Metropolis". The Greek legend of Pygmalion, similar superficially, in reality illustrates how different was the Greek point of view. Pygmalion was an artist, not a scientist. He was not trying to produce an automaton to keep house for him, but to embody in a figure his ideal of beauty. It lived only when a soul was breathed into it in response to his prayers. In our legends, the demoniacal men of science who make the automata often receive back-handers from the artists who write the legends. The automata acquire souls and thus pass beyond the control and comprehension of the men of science. In our day,

however, this artist's way of ending the legend makes us smile. We feel that the soul would be a nuisance both to ourselves and to the unfortunate automaton, whereas we know that a practicable Robot would satisfy a long-felt need.

Our Modern Ideal.—The nature of our practical modern ideal is best seen by studying the mentality of those few amongst us who represent the reaction against it. In every individual we can find, suppressed but not killed, complexes of ideas and desires which have been set aside to make free play for his ruling aim. Some are entirely contrary to his adult tastes or purposes, others are possibilities which have remained undeveloped because the impulse behind them, or the natural gift needed to develop them, were not sufficiently strong. They live on in us as memories, often of an active and disturbing character.

In a middle-aged civilization there are, analogously, groups of individuals filled with a strong spirit of revolt against the dominant direction of energy. Thus there are those among us who derive the greatest pleasure from the sight of a craftsman at work-bench, loom, or last and are filled with horor at the sight of a marvellously organized factory turning

out, almost independently of human labour and skill, objects of utility or luxury. The product of the craftsman, recognisable as his unique personal creation, is valuable to them precisely because it is stamped with traces of the striving of his own weak pair of hands, assisted by the simplest tools, against the matter which he has bent to his will. The vast majority of Westerners are, on the other hand, attracted by precisely the opposite kind of product: work bearing no trace of human hands, produced by a machine, itself almost equally devoid of all individuality, but hundreds of times more powerful and accurate than the hands of the craftsman. We strive steadily towards a life among objects all possessing this inhuman perfection, surfaces uniform in colour, or patterned in endless perfect repetition, form of geometric perfection. It is not true to say that our machines attain a perfection of execution which is the ideal of the craftsman. There is a difference between inhuman and superhuman perfection.

Humanity and Humanitarianism.—Nothing could be more untrue than to suppose that this development is one of necessity, and not of taste. Our theology,

though nominally based upon Judaism, has from the earliest times striven against " anthropomorphism ", however difficult it used to find it to drive the idea out of the popular mind. Our God, by the Articles of our creed, is " without body, parts, or passions ". Where handwork is still indispensable, as in building, it succeeds more and more in disguising its lowly nature, and in producing results which, to our great satisfaction, appear machine-made. In the truest sense of the word, our civilization is misanthropic. More and more, we are averse to humanity. Our " humanitarianism " is precisely the opposite of a love for humanity. It is the expression of our distaste for its natural passions, actions, and reactions. A vast and successful activity carried on in its name strives perpetually, by a thousand different methods, to create communities of well-washed well-fed, well-regulated, well-behaved, mildly cultured people as devoid of all individuality as machine-made automata. For although it is true that the highest and strongest types of individuality and character may be exhibited by persons whose conduct conforms to the most exacting demands of the humanitarian, it is not true of the mass of men. Regimented by the humanitarian, they

become as monotonously alike an characterless as a well-cared-for herd c cattle.

Technology and Humanitarianism.– There is thus clearly a close connectio between the motivation of technolog and humanitarianism. Were no othe influence at work, the activities of th humanitarian would be guided solel by the needs of our industrial civilizatior the ideal of which is the automator the man-made worker free from a individual, distracting, time-wastin tastes and passions, and turning ou products of machine-like perfection.

The Constitution of an Automaton.– An automaton, by analogy with th human model, should consist of thre parts: limbs to work with, senses t perceive what it is working with, or wha result it is producing, and a brain t regulate the action of its limbs i accordance with the perceptions of it senses. Needless to say, we are strivin to create, not a Frankenstein's monste a Robot, a mechanical servant whic can be set to any simple task, bu thousands of different automata eac specialized for a certain task. In ou machines we have already develope *limbs* of a power and precision exceedin our own many many thousand-folc

In our instruments, we have developed *senses* exceeding our own, in many cases, a million-fold in sensitivity. Indeed, they are capable of receiving impressions, such as magnetism, which are qualitatively imperceptible to our natural senses. What we have still to develop is the mechanical *brain*, the link between instrument and tool. At present, we make use in most cases of a human brain. The ship is driven, and its rudder moved, by machinery; the compass senses the direction; but a man still stands at the wheel with his eyes on the compass. Our instruments are means for "amplifying" or translating their subtile perceptions into indications perceptible to the coarse senses of our human agents. The man at the wheel cannot sense directly the magnetic field of the earth, but the compass does so, and translates the result into a movement perceptible to his eyes. His function is purely mechanical. It could be, and indeed, already has been in some cases superseded by a mechanism.

The Human Automata of Modern Industry.—This case is typical of the function of a large number of workers in modern industry. Their task is often of the simplest, most monotonous description. They watch a dial or two, and

move a lever or two accordingly. They copy figures into a book, and add them up. They count or weigh material into packages, rejecting bad stuff.

The steady development of machinery of all kinds, and of highly elaborate processes requiring careful attention to the indications of instruments in order to regulate them closely, calls more and more for a type of employee completely inured to boredom, capable of sustained vigilance under conditions devoid of all incident to rivet attention. From the point of view of industry, it should be the task of the "social reformer" to see that the supply of such semi-automata shall keep pace with the demand, and that they shall be clean, healthy, simple minded, undisturbed by rude passions, whether animal, political, or spiritual; regular in their habits, fertile to a sufficient degree but not beyond it, and dependable in the matter of attention to their task.

It need hardly be said that the individual social reformer is usually completely unconscious of his real function. It is sufficient for him to see people dirty, drunken, quarrelsome, lustful, envious, insubordinate, and to imagine how miserable he would be if he were compelled to be one of them. He regards

the mainspring of his activity as the desire to reduce the sum of human misery; a view undoubtedly correct in its way, though his remedy appears to involve emptying the human baby out with its bath of misery.

Politicians and Industry.—The power upon which the humanitarian draws is the imperative need of the modern state for a contented and docile mass of workers. To some extent, therefore, he is attempting to fulfil this need, but unfortunately, the situation is complicated by the fact that politicians, and not industrialists, carry on the work of government and legislation. Their task is the very necessary one of maintaining order, and the path they have chosen has not, as we shall see later, been that favourable to the development in the mass of the people of qualities most needed by industry.

Competition between Men and Automata.—We must needs take account at the outset of the possibility that the mass of people will be moulded by the various influences at work into products so suitable to our needs that mechanical automata would be more trouble than they are worth. Even were this the case, I do not think that the development of automata would be prevented.

It is a complete fallacy to represent, as certain types of sociologists are accustomed to do, our modern technical progress as inspired and energized solely by greed, acquisitiveness, capitalistic money grabbing, and the like. It would not exist at all, on the contrary, but for the fun it affords to the people whose brains guide it. The owners of the brains do not, as a rule, pocket any but a quiet insignificant share of the profit. They play the great game, and the financiers take the gate. Without their enthusiasm for the game, there would be no gate. When the day comes, as it assuredly will, when our youth regards a scientific or technical career with the measure of enthusiasm which is aroused to-day by a parson's career, technical progress will cease ; nay, a rapid retrograde movement will set in.

The Game of the Politicians.—The players of the game of technical progress are, however, far asunder as a class from the politicians, who are playing their own equally engrossing game. To some extent it falls in with that of the technologists, for both require for their purposes that the mass should be amenable, contented, and devoid of rebellious passions. The work of the humanitarian is thus influenced from two sides, but

the political influence is dominant, since the work is carried on mainly, and every year more, by legislation. That legislation had to be of a type acceptable to the mass, at any rate in the immediate past, even if it need no longer be so now that almost complete docility has been attained.

Discipline v. Emasculation. — The politician has gone his way without reference to the needs of industry. All his attempts to discipline the mass have proved failures, and he has been driven back upon a process of emasculation. For discipline must needs develop stern qualities of conscientiousness, dependability, and loyalty, which are precisely those essential to the success of revolutionary movements. The success of the German revolution was a most striking exemplification of this fact. Emasculation is, on the other hand, a complete success from the politician's point of view, and is further sympathetic to the humanitarian. None but strong personalities escape the effect of modern State schooling, political press, censored cinema, and wireless. The typical men and women of the mass are never thrown on their own thoughts for an instant, for the good of their souls, or upon their own resources to save them from starva-

tion, for the good of their self-respect. They are cared for and shepherded, mentally, morally, and physically, from the cradle to the grave. All development of strong traits of character is necessarily at an end. Such people are useless where character is called for, and hence to the leaders of revolution. But however ideal from the politician's point of view, they are very unsatisfactory to the technical man. He wants a monotonous task performed with the greatest dependability. A mind so simple as to attend to the task to which it is set, from sheer absence of any internal mental distraction, would do; but the mind of the modern worker is not simple. He has been nourished upon distractions of all sorts, press sensations, sports news, every kind of shallow mental titillation. A character so conscientious as to carry out the task in spite of boredom and distracting interests, would suffice; but such characters are not bred and developed under modern conditions. If industry is to be carried on, means must be found for counteracting the loss of the dependable type of worker upon which it formerly rested.

It therefore appears to me certain that the greatest efforts will be made to extend the applications of automata.

True, the automaton of to-day is often expensive to instal, and exceeds in cost the worker it replaces. Too often it is liable to go wrong, and needs frequent attention at highly skilled hands. But these are drawbacks that will be remedied.

The Present State of the Technology of Automata.—This field of work is at present in a most primitive stage of organization, compared with that of other branches of technical science. The initial work is largely done by inventors of the most "classical" type, striving to solve a problem because it happens to fascinate them. Often they are men without the most elementary training in physical and chemical principles. The development into practicability, also, is carried on by men equally ignorant of fundamental principles, for these fundamental principles have never been systematically studied. While the design of prime movers, electric generators, machine tools, and so forth has been elucidated and written about theoretically and practically, there is hardly any literature available concerning the design of such matters as electric relays, contacts, complicated mechanical motions. Nothing at all is published concerning the relative merits and dependability of all the various alternative devices which may be

used to solve an automaton problem. Each problem is attacked by a costly process of trial and error usually devoted to one system only; and a successful result may well be superseded by a solution based upon a totally different system. Technical alternatives will, of course, always exist, but in more developed branches of engineering the relative merits and demerits of alternatives can be estimated from theory and experience before work is begun. No such possibility exists at present in the design of automatic controls, and the establishment of a research and teaching centre to elucidate these problems would be a great step forward. The multiplicity of methods, both in principle and in detail, would be reduced; sound ideas which have remained untested would be brought to light and tested out. The fundamental problems peculiar to small mechanisms would be investigated, whereas no one but the practical constructor seems at present to be aware that such peculiar problems exist.

The Future of the Automaton.—The purpose of this essay is to consider how far we may reasonably expect this development of an automatic link between instrument and machine to go in the future. We have first considered the matter from

the point of view of the human worker, and we have concluded that he will not improve in dependability. On the other hand, it is certain that the automaton can be largely improved and cheapened. Also, that the processes of the future will be more exacting from the point of view of control than those of the present. Hence it is likely that the only limits which will be set to the development of automata will be those inherent in the limitations of our science.

Recording Instruments and Alarms.—We ought to notice, before passing on to technical details, a modern development which represents another method of coping with human frailty. Every kind of instrument can now be made self-recording, and it is thus possible for a works-manager to receive an automatic report each day of the exact manner in which the plant has been worked in the past twenty-four hours. Jointly with this development, we have instruments with giant dials, and others which sound alarms or exhibit coloured lights when all is not well. The moral effect of these devices on the men in charge is very great, and ingenious means are being developed for translating into terms of bonuses and fines the goodness or badness of each record. But instruments

that can do all these things may, in many cases, equally well set machinery going which dispenses with human control. We may still, however, retain our records and alarms. The latter then correspond to the pain mechanism of our automaton. It cries to us in distress when all is not well with its internal economy.

Examples of Simple Automata.—We have already defined the automaton as consisting of three parts, corresponding to the senses, brain, and limbs of the human body. It is thus distinguished from an automatic tool, such as a lathe, which is devoid of senses, and is thus incapable of adapting itself to varying conditions of material or working. Perhaps the simplest everyday example of a true automaton is the gramophone motor. Its function is to turn the disc at a constant speed, in spite of varying friction, strength of spring, and other causes. In it we find a very simple instrument, consisting of a pair of spring governor balls, the divergence of which is a measure of the speed of the motor. This device "perceives" any change in speed, from whatever cause. It acts upon a brake applied to the motor, presses this on when the speed increases, and takes it off when it decreases. This is the brain of the arrangement, which controls the limbs, the motor.

Another very common device is the thermostat, which regulates the temperature of an oven, furnace, cold-

storage chamber, or even an ordinary room. Here we have some suitable form of thermometer (very many forms are in use) which keeps the temperature regulated. It is linked, by mechanisms of the most varied kind, with the source of heat or cold, in such a way that whenever the temperature which is to be controlled rises or falls slightly, suitable automatic action, such as increase or decrease of fuel supply, takes place. This ancient device is being fitted, as a great novelty, to modern domestic gas ovens. It was quite well known when the first gas ovens were put on the market.

The Corrector Automaton. — These two devices are typical of one fundamental kind of automaton. It is a kind which may be said to wait for slight trouble, and then immediately take steps to correct it. The diagram illustrates the principle in an electrical form of quite general application. This form is applied in the automatic steering of ships. Here the instrument is the compass, in practice the gyrostatic compass, though the system might easily have been applied long before the invention of the latter. A minute swing of the compass from its correct set course makes an electric contact, which sends a weak current to a magnetically operated switch capable

of sending a current sufficiently strong to cause a motor to turn the rudder so as to correct the deviation from course.

The Prescient Automaton.—The system just described serves very well for large ships, which are not noticeably deflected from their course by single waves or gusts of wind, as are small vessels. The helmsman of the latter, however, does not wait for these deflections to take effect, but watches for waves and anticipates their effect by a turn of the rudder. It would obviously be a very difficult matter to make an automatic steersman which would act in this case in a manner equivalent to that of the helmsman. But in many other cases it is possible to construct automata which do not wait for trouble to occur, but, instead, anticipate it. Such automata perceive a change in conditions, such as size or composition of material, and immediately adjust the tool so as to meet correctly the changed conditions. As an example we may take the case of softening water by the addition of chemicals which throw down the lime and magnesium salts to which the hardness is due. The dose of chemical added must be exactly proportioned to the hardness of the water. Now the process of softening and settling takes two hours

DIAGRAM OF

SENSE. INSTRUMENT

(such as pyrometer, pressure gauge, speed indicator, compass) measuring whatever the automaton is to keep constant (temperature, pressure, speed, direction).

BRAIN.

TWO FIXED CONTACTS

close together, one on either side of instrument pointer. They are set so that when pointer is touching neither, its reading is the correct constant value desired. The two contacts are connected to a battery and to

TWO RELAY SWITCHES

one of these receives a weak current from the battery, whenever instrument pointer touches one of the contacts: that is, whenever that which should be constant varies in either direction. It then closes and holds on a switch which sets going one of

LIMBS.

As soon as error is rectified, instrument pointer ceases to touch contact, relay switch ceases to receive current, and lets motor switch go. Motor stops.

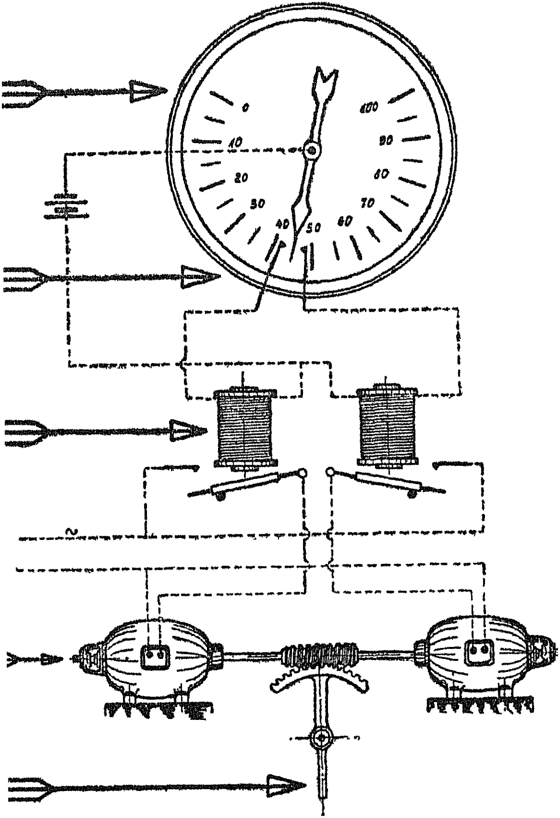
TWO MOTORS

which then moves

REGULATING LEVER

in correct direction to rectify error.

RRECTOR AUTOMATON



to complete, so if we were to try and work on the "corrector" principle, and have our automaton readjust the dose of chemical when it found that the treated water was too hard or overdosed, we should always be two hours late, and the device would work with very great inaccuracy. Instead, we use an instrument (invented by the writer) which analyses the raw water as it enters the plant, and at once adjusts the valves to give the correct dose of chemical. The automatic analyst exactly imitates the usual method by which liquids are analysed by hand in the laboratory, and can thus be used for many other purposes besides the analysis of water. Innumerable technical processes carried out on natural materials, such as ores, wood fibre, vegetables (sugar beet), and so forth, require at present continual control by analysis, since the raw material varies in a way which cannot be foreseen. These processes will no doubt be rendered largely automatic in the future.

The second diagram illustrates this "prescient" type of automaton. The electrical scheme is used merely because it is simple, to exhibit the principle. It is evident that this second type of automaton has inherent advantages which

make it of wide application. Broadly speaking, whenever we can construct an instrument to measure the quality to which our tool or plant has to be adjusted we can construct an automaton of this type.

Sorting.—Perhaps one of the simplest cases of this kind is that of sorting. The scope for future development is here very great, and the problems to be solved are very various. It is of importance to consider it at this stage, because it illustrates very well a matter of fundamental importance to our subject. The problem is clearly one for the "prescient" type of automaton, which should perceive the size, weight, or other quality according to which sorting is to take place, and direct the objects to be sorted into their appropriate receptacles.

Now in the matter of size, the problem is solved in the most complete fashion by one of the oldest devices known to man, namely, the sieve. A series of closely graded sieves placed one above the other in order of fineness will, when set vibrating, separate a pulverized mass thrown upon the uppermost into as many classes of fineness as we may desire. The various products may be passed on to machines each adjusted to treat material of the particular size.

DIAGRAM O]

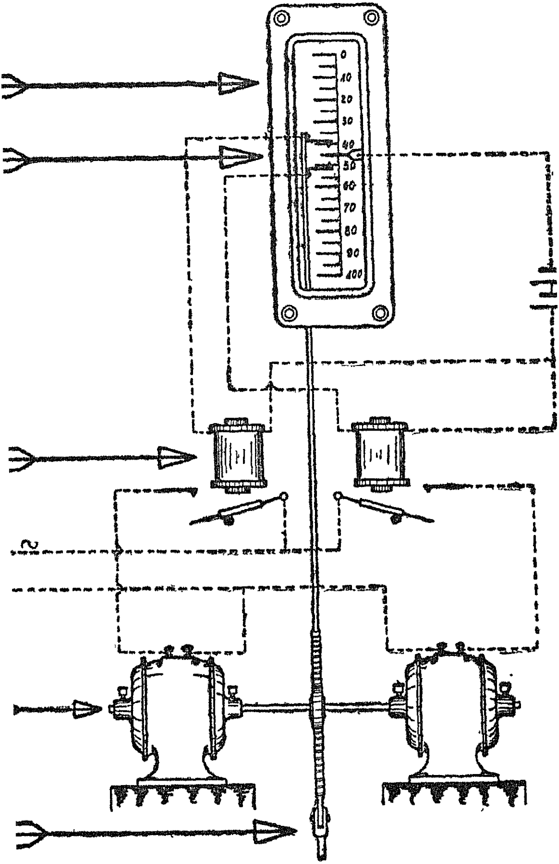
SENSE. INSTRUMEN'
Measuring property of material to be worke upon by automaton (chemical compositior size, electric conductivity)
BRAIN. TWO MOVEABLE CONTACT:
Are on either side of instrument pointer. The are fixed to a rod attached to the regulatin lever (see below) and move over the scale o the instrument as the lever moves. The leve is so geared to the apparatus under contro that the latter is correctly regulated, ii accordance with the indication of the instrument when the contacts (and hence the lever) are ii such a position that the instrument pointe touches neither contact. When it touches on or the other, a current is sent from a batter to one of

TWO RELAY SWITCHES
which then switches in one of

LIMBS. TWO MOTORS
The contacts are moved in the correct direction until the one in contact with instrument pointer breaks away from it, whereupon the relay switch ceases to receive current and lets motor switch go. Then motor stop

which moves the

REGULATING LEVER
and with it the contacts on the instrument.



D

The treatment of ores in mining makes use of this and numerous other classifying devices. The actual ore-dressing machines, which separate the valuable from the worthless material are also closely allied in function. These devices, classifiers, and dressing plant are automata of the most ideal prescient description. But they can hardly be said to be built upon the human tripartite model. They perform their tasks at a vastly greater speed and lower cost than could devices measuring each individual grain, and actuating mechanism in accordance with the result to send that grain to its appropriate destination. They warn us that there may be a way round the anthropomorphic solution of any automaton problem.

Hand-Picking.—Yet in this very field there is a problem which has hitherto resisted all attempts at solution. In treating minerals, it is often very desirable for many reasons to avoid having to crush up the rock containing the mineral to the point at which all the constituents are set free from one another. Often the valuable material occurs in large lumps sparsely distributed through barren rock, and to crush the whole rock would mean heavy expense and great waste. So instead, what is called "hand-picking"

is resorted to. The rock is broken into large lumps, which pass on a travelling belt between rows of workers who pick out by eye the lumps containing valuable material in visibly large quantity. The same process is, of course, resorted to in numerous other cases where good material is to be sorted from bad.

Leaving aside for a moment the question of whether we shall ever succeed in making an instrumental eye to work actually in the same way as the human worker does, it is evident that solutions of the problem are possible in cases where we can satisfactorily perceive what is to be perceived by means other than eye. For instance it should not be difficult to make an automaton to sort lumps of rock or other objects in accordance with their magnetic qualities, weight, or electric conductivity.

It would be impossible to go into details here, but there can be no doubt that a very great development will take place in this field. An immense amount of sorting and counting is done by hand which could be done automatically. Each problem, however, is quite individual. We will therefore content ourselves with considering quite generally the possibilities of automatic sorting or recognition by means analogous to the human eye.

The Seeing Automaton.—Ever since the discovery of the sensitivity of the element selenium to light, which causes it to change its electrical resistance very greatly, inventors have promised themselves the most marvellous results by an application of its properties. It was early proposed to switch street lighting lamps on and off automatically as required by means of a selenium cell which would "perceive" the amount of natural light, and operate the switch accordingly. A recent invention is Mr. Fournier d'Albe's apparatus by which the blind are enabled to read ordinary print. Of recent years other forms of cell sensitive to light have been constructed, which have been recently written about a great deal in connection with television. We need not therefore enter into detail here, but content ourselves with noting that all these devices can be made part of an electric circuit, the current in which varies in intensity according to the amount of light falling on the light-sensitive cell. Nowadays we have extraordinarily simple and sensitive means for detecting and amplifying small variations in electric currents. They are known to every user of wireless receivers. We may safely prophesy that the day is at last at hand when a perfectly

satisfactory and highly sensitive "light-relay" will be available; an apparatus, that is to say, that will respond to light falling upon it by good strong variations in an electric current, which can then be set to work any kind of apparatus.

Possibilities of the Seeing Automaton.—The writer is, indeed, puzzled to know why such an apparatus is not already on the market. Its applications would be innumerable. The old scheme of turning artificial light on and off automatically according to need could at once be put into practice. Races could be automatically timed by sending a beam of light across the track into a light-sensitive relay, which would start or stop a chronograph when horse, man, car, greyhound, or other competitor interrupted the beam for a moment. Objects of any sort passing a given point could be counted by similar means. The advent of vehicles at cross-roads could be signalled in advance.

Many of these things could be done, by the way, by apparatus much less delicate than a light-relay, since the beam of light could be powerful enough to actuate a relay sensitive to its heating effect.

But the applications to the construction of automata of a highly sensitive relay would be innumerable. They would

present no difficulty wherever the human hand is guided by colour, as in hand-picking, sorting of fruit and other natural products, testing eggs by transmitted light, controlling chemical processes where colour is a guide, dyeing, and colour printing.

Limitations to the Powers of the Electric Eye.—Let us now consider the limitations of our electric eye. We may assume that there is no limit to its sensitiveness, and that it could be made to react with certainty to the minutest variations in light of any selected colour. The limitations we are about to consider are of a different description, and raise one of the most fundamental questions of our subject. Very low forms of life possess a faculty of responding to visual impressions which depends, not upon an extreme sensitiveness of the eye, but upon the comparison of the impression received at the moment with past impressions stored in the memory, the latter word being used in the widest sense, of a "conditioned reflex". Once an animal has experienced what food, or an enemy, looks like, it afterwards responds to the visual impression in a reflex, that is, a purely automatic fashion. Now this faculty has a further peculiarity, namely, that it is not limited to recognition

of an impression exactly like that which originated the reflex, but is equally well exercised by similar impressions. An animal responds by instant flight to an impression of human beings of the most varied sizes, shapes, and colours. It appears to have a general idea of what men are like, and is able to compare a visual impression with this general idea (not always correctly, of course) and judge whether it has been received from a human being. It need hardly be said that I am not suggesting any kind of conscious comparison; the whole process takes place, not only in animals but in ourselves, in a purely reflex fashion. Even fish are said to recognize individual human beings who feed them regularly, and they certainly respond instantaneously to the flight of a bird enemy over the water.

How far can we ever hope to imitate this in our automata? Could we ever, for instance, devise an apparatus which would signal "sail ho!" at sea?

Let us proceed step by step. Fournier d'Albe has given us, in his reading machine for the blind, one hint of a possible solution. A tiny camera serves as its eye, taking in one letter at a time, and projecting an image of that letter upon a screen. The screen, like our own

retina, is a network of separate light-sensitive spots. In his machine, it is true, the impression on the artificial retina is converted into sound in a telephone applied to the ear of the blind reader. Each spot on the retina plays a certain note when it is excited by light, and the reader thus learns to distinguish the particular mixture of musical sound which corresponds to each letter. We could, however, equally well arrange that each sensitive spot, when excited, should transmit the effect to a set of indicators on a board corresponding to the retina. Say the image of a white cross fell upon the instrument. Then, let us say, studs lifted by little magnets would rise up on the board to form a sort of image of the cross. How is our automaton to be made to "know" that this is a cross, and to do whatever we want it to do when it receives the image of a cross? Obviously, if all we ask is that it should respond to a particular size of cross set the same way every time, the matter is quite simple. The same set of studs would rise every time, and we have only to arrange that that particular set shall complete an electric circuit. But if we demand a response to any cross, no matter what size, but to no other shape; or worse still, to a

cross of any size in any position, the problem will need some hard thinking. We will return to it later, and see whether we can imagine some solution.

We may safely say, however, that we could devise a machine which would typewrite, or set type, from a typewritten or printed page presented to it. It would be highly complicated and expensive, but it could be done. It would be in the nature of an adaptation of the blind reader.

The Automaton which Reads Manuscript.—Suppose, however, the ingenious constructor were now asked to adapt his machine to read manuscript, or even type of different size and "face". The difficulty would be stupendous; I should say insuperable. Our automaton has to "recognize", not a given thing of fixed size and shape, but the class to which a vast variety of similar sizes and shapes belongs.

Automatic Traffic Control.—Another example is the problem of automatic traffic control. A good light-sensitive relay would, as I have already remarked, readily enable a signal to be sent that *something* was approaching a cross road. It would be next door to impossible, however, to signal "man," "car," "horse and cart," let alone "policeman,"

"Ford," "Rolls-Royce." It is not, impossible, however, that we could imitate the sensitiveness of men and animals to movement in the field of vision. We might even be able to signal "object moving rapidly", and like matter, but it would be very difficult.

It appears to be worth considering whether this problem of the automatic signalling of traffic might not be approached from quite a different side. All the vehicles the advent of which requires to be signalled are made of magnetic material, and it would be a perfectly easy matter to arrange that the passage of such a vehicle at a point some distance from the cross roads should cause a signal to be exhibited there, which would be washed out again at the moment when the vehicle reached the cross road. The difficulty would be to avoid the complete disorganization of the system by vehicles not behaving in a regular fashion.

The Ear of the Automaton.—We pass naturally from sight to sound. A brilliant achievement in this field was the development of sound ranging during the war. As with the eye, so with the ear; our device will respond to a certain sound by sending or varying an electric current. Given such a response, and we can do

almost anything with it by modern methods. Recent inventors have been busy with devices which respond selectively to certain notes of the musical scale. Others make use of sound waves in water and other media. As sound is propagated at quite a slow rate it is possible to measure distances automatically by sending out sound waves and noting the time they take to reach their destination, or to be reflected from it and return to the sender. Very successful devices of this kind enable ships to take soundings to any depth.

It is extremely likely that sound-perceiving instruments will, in future, play a part in the construction of automata. They may well serve as means for detecting the nature of media, whether solid, liquid, or gaseous. For instance, the pitch of the note of a whistle depends upon the nature of the gas used to blow it. This fact was used by Haber to construct an extremely simple means for indicating the presence of dangerous gases in the air of mines. He used two whistles, which were tuned so as to be of exactly the same pitch when blown by the same gas. They were taken down the mine, and one was blown by the air of the mine, while the other was blown by pure air from a

cylinder of compressed air. A very small amount of fire-damp sufficed to cause a slight change in the note of the former whistle, which then "beat" against the one blown with pure air. Our ear is very sensitive to beats, that is, those most unpleasant oscillations produced when two notes very close in pitch are sounded together. A sound-relay sensitive to beats could, of course, readily be constructed. The field is worth the attention of inventors, and should afford them a great deal of amusement. Not profit, of course. Pioneer invention is the least financially profitable pastime that exists; or rather, the most disastrously unprofitable.

The Automaton that Types to Dictation.—Every now and then we hear from the inventor who plans a typewriter that will write to dictation. This may appear to the non-technical no more fabulous than a forecast of the achievements of wireless would have appeared twenty years ago. But the cases are not on all fours. I venture to say that if any technical problem can be flatly termed insoluble, this is one. We are brought back at the start to the same type of difficulty as that discussed in connection with the electric eye, namely, of the "recognition" by our automaton of

similarity, and not identity. The voice and pronunciation of every person differs very greatly. Were we to succeed, however, in making an electric ear which would respond in the same way every time to the same sound, it would still respond only to syllables, and not to letters. Its only conceivable response would be a sort of pattern corresponding to each syllable, which would then have to be sorted automatically amongst not 26, but thousands of possibilities. Finally, of course, the matter of spelling would present entirely insuperable difficulties, since the human typist can only decide by the sense whether to write "w o o d" or "w o u l d," and often decides wrongly.

This matter, however, takes on a somewhat different aspect when considered in connection with the endeavours, so persistent and yet hitherto so unsuccessful, towards the formation of a universal language. The latest suggestion of the kind, however, appears to me to have far more prospect of success, and, curiously enough, to reopen the question of the typist automaton. I mean the plan for the simplification of English proposed by Mr C. K. Ogden. He hopes that when his present researches are completed it will be possible, by a new and fundamental analysis of the mechanism of

language, to produce a modified English with a basic vocabulary of about 500 words in which almost everything can be expressed.[1] It is certainly within the bounds of possibility that an automaton might be devised to take dictation in this language from a practised speaker, provided only that no ambiguities of sound occur in the final vocabulary.

The recording of sound upon the photographic film, now in commercial use in the talking film, should have a future in connection with office work. It would enable a record, secret if desired, to be made of important conferences or interviews. It would be a much more capacious and handy apparatus than the dictaphone. It could, of course, be used to avoid typing altogether by sending records of spoken messages by post; an early dream of the future, which was common when the phonograph was first invented. It should also find a wide application in the construction of automatic announcing devices, such as would be very useful to railways.

The Recognition Problem Again.—It is not at all impossible that light might be

[1] A specimen translation of pages 44–50 of the present work appears as an Appendix. The vocabulary is constructed from an ingenious system of panoptic conjugates.

thrown upon some of the fundamental problems in psychology by close study of recognition. We can only go so far here as to discuss visual recognition a little more in detail, and leave the reader to consider it further for himself. A lens throws an image of a shape upon a screen made up of light-sensitive spots. Can we arrange matters so that when and only when, a certain shape appears on the screen a certain response is given? The answer is certainly, "Yes," if the shape is the same size and occupies the same place every time. Can we further provide the apparatus with a repertoire of shapes, so that it gives a separate signal for each shape in its repertory? The answer is "Yes," if the same shape always occupies the same part of the screen. Suppose it does not? It is quite conceivable that the apparatus might then be made to centre itself automatically upon, say, the centre of figure of the shape, whatever it was. It would get a general disturbance, "figure in the field," and then proceed to move until it was "looking" at the centre of the figure. The image of the latter might then, however, be set at the wrong angle for recognition, so that the next step of the automaton would be to turn the screen right round the compass.

If recognition still failed, it might be because the figure was too large or too small. It would then be necessary to arrange that the automaton would change the size of the image on the screen (by optical means) in minute gradations, and test out each gradation all round the compass. It would no doubt require a lifetime of work and a fortune in money to construct a workable apparatus of this kind, but it would not be impossible.

When, however, we tackle the question of the recognition by the automaton of a number of similar but not identical forms, the only solution we can think of is one which simply enlarges the repertory of the automaton by a number of *definite* shapes. It is, however, pretty certain that this is not Nature's way. The mental process is no doubt a sort of working to limit gauge. The same shape is recognized as the same until distortion has proceeded in various directions up to a certain point. But in the mental process, the shape appears in some way to be taken out of the three dimensions of space. The mirror image of a completely unsymmetrical shape is at once recognized as the same, or nearly the same, as the original.

Colour.—Colour is an entirely different matter. The recognition of colour by

a sensitive relay would be quite a simple matter, for light can be filtered by screens so as to pick out any desired part of the spectrum, or, if that be not fine enough, a prism may be used. The applications to industry will be numerous. Wherever the human hand is guided by colour, the automaton could take its place. Thus in hand-picking and sorting by colour of natural objects, such as minerals, fruits, eggs, and so on, automata can be safely predicted. Mention has already been made in the press of an automatic device for picking out cigars of bad colour. Chemical processes are often controlled by observations of colour, turbidity, or other optical properties of the substances, and all these controls could well be made automatic.

Colour as a Label for Automata.—We can readily imagine that colour might be chosen as a convenient label to attach to objects of different sorts which are to be dealt with automatically. Cards could readily be sorted in accordance with their colours, and this might find application in automatic systems of accounting and book-keeping, instead of, as at present, the use of a code of holes punched in the cards. A standard-sized envelope with a certain repertory of colour schemes might be used to enable

the automatic sorting of letters. One imagines that the labour-saving despatch of letters in the future will involve automatic correct franking according to weight, by the insertion of a coin, or, in the case of business houses, by the use of a franking counter of the kind recently introduced. The letters would then be automatically sorted by colour, it being, of course, a matter for the sender to use an envelope of the correct colour, appropriate to the destination. The old-fashioned style of things could be kept up alongside the new, with appropriate excess of cost to those who preferred to send their letters in envelopes of their own choice.

It is obvious that the light-relay could equally well be made to respond to patterns printed in black on the white envelope, each destination having a particular key pattern.

Even at present, it is surprising that the post-offices of the world do not combine to bring pressure to bear in the direction of uniformity, of stationery, address, and so on. Hand-sorting would be greatly facilitated.

The Automatic Kitchen Maid.—The matters we have just discussed have carried us very far beyond immediate possibilities. We may now return to

ome cases where, as in the matter of izing already dealt with, we may expect ın automaton to be built upon a way ound, rather than upon the anthropo- norphic model. A most important natter is the stoning of fruits, peeling otatoes and other fruit or vegetables, racking nuts, and generally speaking, lealing in a simple fashion with material f great variability. Here the field for nvention is large, and not quite so hope- ess in the matter of profit, as are nany other fields. People are actually dvertising for someone to invent nut racking machines.

Now it is a commonplace remark that ur machines, for all their power and lelicacy, are not yet equal to many of he operations which the human hand erforms with ease. Particularly in he matter of adaptability to variable naterial is the hand the superior of the nachine. Nevertheless, these problems vill certainly be solved sooner or later. Jnfortunately, they are so various that t is impossible here to enter into technical letails. We may, however, glance at he question of the competition between and and automatic working, as in this eld it is by no means on all fours with ther cases we have considered. In he first place, the hand workers are able

to act as pickers of the material, and t
reject bad stuff. In the second, th
work requires, not passive attention, bu
active labour, usually at piece-wor
rates. The workers are generally feminin
Now women develop under such conditior
the most astonishing speed and skil
The whole work is done in an almos
automatic fashion. They chatter awa
merrily as they work, but once th
necessary skill has been acquired, th
quality of the work almost exceeds tha
possible with conscious attention. I
becomes like walking up a familia
flight of stairs in the dark—best dor
without thinking about it. Here a
that we have said about the decline i
the quality of labour falls to the groun
A low grade of intelligence is a positiv
advantage. It is, in fact, unusual t
find anything else among persons suprem
in skill of this unconscious kind, such a
certain types of musical executant
athletes, players of games, and so o
Intelligence and even the higher trai
of character are positively inimical. A
that is required is natural muscular ski
and persistent practice.

Nevertheless, there is another fact
which outweighs what has just bee
said. A very great deal of this wor
is of a seasonal character, and hence

is frequently difficult to make sure of a sufficient supply of skilled labour. Also, the supply of material may often vary greatly from season to season.

Hence there is a steady call for machines of all sorts for this kind of work, and there is also a vast variety of solutions to choose from. It is probable that many possible types have not yet had a fair trial at the hands of persistent and skilled experimenters. The general public hardly guesses the cost of developing even the simplest mechanical invention. It is rare indeed for that cost to be covered by successful results. An inventor must be highly skilled in the use of tools and well provided with them, or he must expect to spend thousands of pounds to gain success.

The Mass Production of Machines.—We may now consider a field of work not without its analogies to the one last considered, namely, the mass-production of machines and contrivances, from motor cars to small matters such as vacuum cleaners. Here the mechanical production of the separate parts is brought to the highest stage of perfection by automatic tools working on material of great uniformity. The fundamental principle is that of working to limits of size. A very careful study of the machine to be

mass-produced renders it possible to assign to every part certain limits of size within which that part may vary without losing the property of being interchangeable. It is, of course, impossible for the finest machine to produce even two objects exactly alike in every respect, let alone a large number. The tools used for stamping or punching or turning are subject to wear. The machines used never run perfectly truly. The material also varies in size and hardness to some extent. Changes in temperature, speed of machine, and lubrication all result in some change, no matter how minute, in the product. But we know by experience what it costs to produce objects in large numbers with any *stated* degree of accuracy as to size, that is to say, so that all the articles produced shall be smaller than one and larger than the other, of two given limiting sizes. The greater the accuracy, the greater the cost. Hence it is possible to calculate quite accurately the cost of mass-producing a given machine when the limits for each part have been calculated.

The object of production of parts to limits is to abolish "fitting" in the process of assembling the parts to form the finished machine. The parts are to

go together just as if they belonged to a working machine which had been taken apart and was being put together again. Assembling thus becomes a purely mechanical operation, the more so as it is usual to inspect the finished parts before handing them over to be assembled. They are tested by what are called limit-gauges. Thus the limit-gauge for the boring of a cylinder consists of two plugs of metal, one slightly larger than the other. If the large one refuses to enter the cylinder, while the small one can be inserted, then we know that the size of the cylinder is intermediate between the two plugs.

Automatic Testing and Assembling.—How far is it likely that these two operations, of assembling and testing, will be performed by automata? As regards testing, there is a continual progress in the direction of rendering it automatic. It calls for labour of a responsible kind.

But assembling is quite another matter. Modern motor factory methods are sufficiently familiar to need no description here. Assembling itself is broken up into a large number of separate simple stages, while the rate at which the worker at each stage works is fixed by the rate at which the work comes to

him to be done. He develops in the highest degree pure unthinking skill at the particular operation. To replace him by a machine would, no doubt, be perfectly possible in almost all cases, but only by designing a machine especially to perform that particular operation. But the capital cost and amorticisation although they might well still show a profit on hand labour, would add heavily to the already very heavy capital investment. After all, no one can say for certain that any such invention will be profitable, since sudden changes of fashion or technical methods may well render the apparatus out of date and unsaleable, while still in process of production.

There is also another point to consider. Automatic assembling would be greatly facilitated by the use of entirely different methods of construction. For instance, nuts and bolts are designed for assembly by human hands. A machine to insert a bolt and screw home nut and lock-nut would be a fairly complicated affair, but it would probably be possible to replace the nut and bolt by another type of fastening more amenable to the automaton. But the finished machine is destined for use in circumstances which may make repair necessary, or replacement of worn parts, and this has to be done by hand.

Hence the machine must be constructed so that it can be readily taken apart by hand.

The Skill behind Mass Production.—We might note, in passing, a matter of great importance in this connection. Modern industrial development does not depend solely upon those who have acquired the ever-growing mass of scientific and technical knowledge necessary, and who make use of it to direct running, maintenance, construction, and development, but also upon those who possess the high degree of manual skill and training necessary to construct the elaborate machines and instruments which are made use of. In the beginning manual skill is necessary, at any rate at present. The making of a press tool, for example, is a matter of hand work of the most skilled description. There are, however, indications that this may not always be the case. There is a piece of mechanism in use for shaping the hulls of ship models to be tested in tanks. The model is made of wood covered thickly with wax. It is shaped quite roughly to correct size and shape, but left a little large everywhere. The hull is then fixed firmly in a sort of frame. Adjacent to the frame is a board upon which the drawing of the correctly

shaped hull as designed by the architect is pinned. The lines of this drawing are traced over by a pointer, and this pointer is geared by suitable mechanism to knives. As the attendant moves the pointer along the lines on the drawing, the wax surface of the model is cut by the knives to exact correspondence. This machine embodies a principle which has very great possibilities for the future. We may eventually develop methods of cutting metal which would enable it to be applied directly to the construction of machine and tool parts to drawings by persons of little skill.

Counting.—We may now consider another case in which the call upon the human intellect is of the simplest description, and hence the field for automata is a promising one, namely, the operation of counting. The application of automatic methods is here making rapid progress, but there are many directions in which applications of mechanical counting could still be made. For instance, the annual disturbance of stock-taking might be largely avoided. Very simple and cheap counters could be made to record, on a central board, the taking in and taking out of stock as it proceeds. The counter on the board would indicate the stock held at the moment. Instead

of this, work is often at a standstill while time is spent counting thousands of articles of trifling value, for the purpose of the insertion of that value into a balance sheet. As, however, the other items on the balance sheet are estimated, very often, with a margin of accuracy of hundreds or thousands of pounds, the estimation of the stock to the nearest penny is an unscientific procedure.

Only quite recently was the proposal to introduce electrical indicators of the number and position of seats vacant in a theatre or cinema carried into practice in America. The system could readily be extended. One might be enabled to select a vacant seat and pay for it by the insertion of a coin in a machine, receiving a check which would serve as a key to enable that seat to be tipped down for use.

Accounting.—There is no need to remind the reader of all that has been said concerning the life at the ledger. Until the development of mass production, it stood uniquely for all that is most monotonous, mechanical, and dreary in human bread-winning.

Machinery is already in use by which a very great deal of the purely mechanical work can be eliminated. It depends fundamentally upon the same principle

as the well-known Jacquard loom. Whatever is to be recorded is translated into a code of holes punched in a card. This card is then inserted into a machine, which is supplied with fingers or electric contacts which come up and look, as it were, for the holes. According to the combination of holes found, certain records are made, or the card may be passed on to another machine to be dealt with. We may imagine an order coming in for so many size so and so things at so much to be delivered in such and such a time. All this may be translated into the hole code by a single clerk. The subsequent operations of booking the order, notifying the correct department, checking the delivery time, totalling by classes all orders received, deducting goods when taken from stock, and invoicing them, could be performed mechanically. Moreover, the hole code can always be made to translate itself back to legible type, though the reverse operation would fall under one of those very difficult cases which we dealt with earlier.

The still simpler operations of banking afford a large field for such developments. The German Postscheckamt, an institution which enables small sums to be paid by the simple process of dropping a

card in a post-box, has installed a system of this kind. Perhaps, after a time-lag similar to that which the C.O.D. system required, we shall be blessed with this convenience elsewhere. Bankers, however, seem to possess a passion for dreary architecture of a very expensive kind, rather than labour-saving systems.

The Automatic Steering of Ships and Airplanes.—We have already mentioned the matter of automatic steering of ships, and we may now consider it in somewhat greater detail, as it is one of considerable interest to the general public.

Such mechanism is always of the corrector type of automaton. We have referred to the use of the compass for this purpose. For some not very obvious reason, it is only quite lately that this possibility has been realized in practice, the type of compass being the gyrostatic, a very recent invention. The ordinary magnetic compass could, however, be adapted to the same purpose.

The automatic steering of an airplane is, however, a somewhat different matter. Here any kind of compass behaves very badly, and in any case, automatic steering by the compass would be of little use. In practical navigation, the airman uses what is called a turn-indicator, which consists of a simple spinning gyrostat

hung in bearings. This is not to be confused with the gyrostatic compass, which tells the true direction of the earth's meridian. The turn-indicator, on the other hand, simply swings to one side or the other whenever the plane deviates from its course in one direction or the other. The airman is thus enabled to keep a dead straight course for time long enough to enable his troublesome compass to settle down and tell him what the course is. He can then correct it if necessary.

This simple apparatus may obviously be made to act upon the rudder in the way we have grown familiar with, so as to cause any deflection from the course to be automatically corrected.

This is the pilotless plane in its simplest form. In all the principal countries, the greatest efforts are being made to devise apparatus of much greater elaboration. The problem is, of course, to steer a plane correctly by automatic means to any desired objective, in order that it may deposit there as much high explosive or poison gas as it can carry. Merely setting the plane on a straight course will not do, for the variation in the direction and strength of the wind would inevitably destroy any accuracy of aim. Efforts are being made to control from

the ground or the air such pilotless planes, but at present this involves two disadvantages that make the prospect of doubtful value. In the first place, it would be only possible to observe the pilotless plane in daylight, and it would then be equally visible to the enemy, and could easily be destroyed. Secondly, the use of wireless radiation as the means of control would be easily rendered futile by the enemy, unless it were so constructed as to be safe from jamming. However, work of this kind is so much more attractive to the inventor than work in conjunction with financiers out for quick profits, that it is sure to occupy some of the very best brains available. Methods of fantastic originality and difficulty can be tried out, regardless of expense. The moral aspect of the matter will play very little part. After all, the work of the inventor of automatons is in any case to abolish unnecessary human beings.

The Universal Automatic Pilot..—We have already said that the difficulty of automatic navigation of airplanes lies in the fact that the effect of changes in the strength and direction of the wind cannot be taken account of. The compass, or similar instruments, tells the navigator in what direction the head of his craft

is pointed, but it does not tell him in what direction, relatively to the earth's surface, he is really moving. Similarly, a log or speed indicator on a ship or plane tells the navigator his speed relatively to the water or air around him, but not relatively to the earth. The physical principle of relativity asserts that it is impossible to construct an apparatus that will do this, unless it is linked in some way with the earth. There must be some physical connection of some kind. When the navigator can see the earth, he can easily ascertain his speed and true direction by observing the rate at which objects on the earth appear to move across the field of a telescope. But we have not yet devised means of seeing the earth which clouds will not interfere with.

There, is however, a possible solution which is so interesting that it may be discussed here. Relativity denies the possibility of the pilot's ascertaining at any instant the true direction and amount of his velocity, relatively to earth, by means independent of connection with the latter. But this does not mean that he cannot measure the amount of any *change* in that velocity, whether produced by changes in the power of his engine, or changes in direction or speed of the air currents in which he is immersed.

On the contrary, as all travellers know, we may be unconscious of the speed at which we are travelling, so long as it is uniform, but any change in it is at once perceptible to our physical sensations. Not only so, but loose objects in the vehicle in which we are travelling are also affected. A piece of luggage falls off the rack, or a bottle upsets. In fact, a heavy object in the carriage behaves, when the vehicle accelerates or slows down, as if it were subjected to a push, opposite in direction to that in which acceleration is taking place. It is thus quite easy to measure in a closed carriage the acceleration; a simple pendulum suffices. Hang a heavy object by a string from the rack next time you travel by train. When the train is at rest or travelling at a uniform speed, the string will be vertical. When the train accelerates, the suspended object is left behind, as it were; the string points in a direction opposite to that in which the train is travelling. When the train slows down, the object carries on, and the string slopes in the same direction as that in which the train is travelling. The deflection of the string from its original vertical position is a measure of the acceleration or deceleration of the train.

The next point is not quite so easy to

grasp. Take the case of the train starting from rest. The pendulum deflects by an amount which indicates the rate at which the train is increasing its speed. If you then observe for how long the pendulum is deflected until the speed becomes uniform and the deflection ceases you are able at once to calculate the speed which the train has attained. The deflection of the pendulum indicates that the train is increasing its speed in one second, by so many feet per second or miles per hour. Thus if we find that the train is increasing its speed by one mile per hour every second, then it is evident that if the pendulum indicates this rate of increase of speed for a period of a minute, at the end of that time the train will be moving at the rate of sixty miles per hour. It is possible to devise a mechanism to do this sum mechanically that is, to sum up every deflection of the pendulum multiplied by the time during which it has persisted. The mechanism would, of course, take account of slowing down as well as speeding up and present at any instant the sum total of positive and negative effect. This sum would be the true speed of the vehicle at the moment.

Furthermore, it would be the true speed relatively to the starting point

Let us imagine ourselves in an airship anchored by the nose to a mast. Let there be a strong wind blowing. We set the propellers in motion until the power they develop is just sufficient to overcome the wind, so that we can cast the nose of the airship adrift and she remains stationary relatively to the earth. If, however, those on board could not see the earth they would imagine their ship to be moving through the air at a certain speed which would be exactly equal, and opposite in direction to that of the wind. It is obvious, however, that a pendulum on board would not have been deflected, and hence its adding device would indicate zero, the true speed of the ship relatively to the earth. If the wind suddenly drops to nothing, the ship will bound forward, and we, and our instruments will certainly be conscious of that bound. The ship will now, provided it continues to work its propellers at the same speed, attain a speed relatively to the earth equal but opposite to the original speed of the wind, and this will be truly indicated by our instrument.

We can thus see that the problem is fundamentally soluble on these lines. The practical difficulties are, however, very great. For while the accelerations due to the ship's or plane's propelling

force are considerable, the accelerations or retardations due to air or water currents are very small in amount, but may continue for very long periods. Thus the plane may get up to full speed in a minute or two, while a wind may spring up against it, and take an hour or two to attain a speed, say half as great as that of the plane. The speed of the plane relatively to the earth is now half what it was at the start, but the retardation due to the wind has never been more than a small fraction of the original acceleration of the plane. This means that our accelerometer must be of extreme sensitiveness over a very long range, and this is the most difficult condition that any instrument can be required to fill. Nearly every instrument has a limit of accuracy expressible as a fraction (say 1/1,000) of its total range. Thus, when it is indicating at the top of its range, it is doing so with an accuracy which may be expressed as one in a thousand. When, however, it is working say at a hundredth only of its full range, its accuracy is only one in ten.

The problem presents other and even greater difficulties, but its fascination and importance must not lead us too far in discussion.

Seeing the Earth by means other than

Light.—Another hopeful line of development consists in the possibility of finding some means of physical connection with earth other than light rays. Other kinds of ray are hardly practicable, though infra-red rays have some dim chance of utilization. The difficulty is, that we must needs form an image in an optical system of objects on the earth. Obviously, when there are no objects, even seeing the earth is no use to us, as over the sea. The use of the earth's magnetic field has been suggested. A wire stretched across the plane at right-angles to its direction of motion is cutting the magnetic lines of the earth's field at a rate proportional to the true speed of the plane. Hence, according to the principles of electro-magnetism, a minute electrical voltage is developed between the ends of the wire, just as if it were a wire of the armature of a dynamo. We might hope to measure this if we could lead it back to our voltmeter. Unfortunately, the wires we should need to use would also cut the earth's lines, and hence neutralize the effect on the instrument. This is an interesting problem for those who know something of electricity and magnetism to puzzle over. If it could be solved, we should at once be able to tell both the true direction and the true speed of the

plane, if we knew the strength and direction of the earth's field at the place of observation. We should thus have to know the position of the plane pretty accurately.

Another possible plan is as follows. If you move a magnet near a conductor, the magnet experiences a slight drag, due to the eddy currents induced by its field in the conductor. The earth being a conductor, a magnet on the plane experiences this drag. Unfortunately, a magnet is a heavy thing compared with the drag it experiences, and the earth is a bad, and worse still, a variable conductor. The drag on any conceivable magnet at any reasonable height would be excessively minute. But of recent years we have grown accustomed to measuring the incredibly minute.

The Railways.—Let us pass from considering the most recent means of transport to the question of one which is now regarded by many as doomed to gradual extinction ; I mean the railway. One may truly say that the running of most of our railways is almost medieval from the standpiont of modern technical possibilities. Miniature railways are run in many towns for postal purposes entirely automatically. Very nearly the same thing could be done with a full-

sized railway transporting passengers and goods, provided of course, it was electrically driven. The tube railways have already shown the way. There is no reason at all why one should not purchase a ticket to Aberdeen at King's Cross in exactly the same way that one purchases a ticket at Liverpool Street for Dover Street, from the man at the barrier. There is no reason why the Scotch express should not be a train in charge of one man, with automatic doors. There is no reason at all why it should be greeted at intermediate stations by hosts of officials. There is no sense in the present elaborate system of dealing with luggage. The taximan should dump it onto an automatic weighing machine which would discharge a printed ticket. A porter would then put it on the train in the same coach as the passenger, who would pay for it at the barrier as he took his ticket, on the base of the check from the weighing machine.

It is impossible to foresee whether the capital will be found to modernize our railways. It is possible that they will revert to a primitive simplicity. Fifty years hence, railway men may be as unmodern and picturesque a class as bargees to-day, sleeping with their wives and families on their trains, and carting

heavy goods slowly about the country, by means of steam locomotives, in a fashion even more primitive than that of to-day. The alternative is complete electrification, with a service of trains at very frequent intervals but moderate speeds, each manned with but one official. The driving could be made purely automatic; the word is a misnomer in connection with a really modern railway such as the Tube. The official in charge would press the starting button; the journey of the train to its stop at the next station would then be purely automatic, and safe against any mishap short of a landslide onto the line. If it arrived at a block in which another train still lingered, it would be stopped automatically. All this is possible by means already well tried. I am inclined to think that it will come sooner than we expect. Train speeds are quite unnecessarily high; comfort and absence of overcrowding would compensate for their reduction, while rapid travel in case of urgent need is provided for by the airplane. The capital cost of modernizing would be high, but the main item would be electrification, which is already being carried out rapidly on the Continent. The automata part of the business would be a comparatively small

item of cost, provided that previous experiment had enabled a standardized equipment to be produced by methods of mass-production. It is high time that the experimental development of these modern possibilities be put in hand in a small closed area such as the Isle of Wight, in charge of competent engineers.

At the time of writing, an omnibus is being put on the road, provided with sleeping berths, which will do the journey from London to Newcastle during the night at less than third-class fare. It is an evident folly to transport passengers over a rough, hilly winding road, in the dark, with their safety dependent upon the nerve and skill of the driver, when they could be transported with much less expenditure of power over a smooth steel road requiring no driving in any real sense, and watched over by automatic signalling in the surest possible fashion.

The Automaton in Power Generation.—One of the greatest advantages of the electrification of railways is the possibility of introducing the automaton principle in the generation of the power by which they are run. In few fields of modern technology is it more widely applied than in power generation. One can buy quite cheaply small electric generating plants which are complete automata; they

are widely used in country places. In Denmark (but in no other country as far as I am aware) one meets almost everywhere small automatic plants driven by wind power. These all depend upon the principle of keeping a battery of accumulators charged. As soon as an instrument indicates a drop in the charge, the dynamo is automatically set in motion to remedy the defect.

In large power stations such a use of accumulators would be out of the question, but the automatic regulation of the voltage produced by the dynamos has reached a state of the highest perfection. The periodicity, in the case of alternating current, is also regulated with the greatest exactness, and a by-product of this accuracy will in the future be of great importance in connection with automata.

A New Kind of Clock.—Modern current supply is almost exclusively alternating that is, the current changes its direction many times (usually 50) per second. Now alternating current may be used to drive motors of many different types, one of which is the so-called synchronous motor. This type of motor works by exactly keeping time in its rotation with the alternations of the current; the number of revolutions it makes thus

bears some simple proportion to the number of alternations of the current. It has either to work at this speed and in this way, or not at all. Hence, if the rate of the current-alternations is timed very exactly, the motor which it drives also revolves with the same constant accuracy of speed. Such a motor may then be used to turn a clock train in place of spring and pendulum or balance. So accurate is the alternation of modern current, that a clock run in this way keeps good time. Furthermore, it is only necessary to have a clock of this kind at the central station, and observe its timing, in order to make any slight correction in the rate of alternation of the current. All other clocks connected to the network will then be corrected at the same time. The immense advantage of such a clock, apart from its simplicity, is the unlimited power behind it. Its rate does not depend upon the work it is called upon to do. So long as this is not great enough to stop the motor altogether, the clock runs true to time.

Inventors and Clocks.—From the earliest times inventors have had visions of doing marvellous things automatically by the use of clocks. They have always been hampered by the fact that you cannot get a clock to go accurately if you try

and make it do work. Hence, it is necessary to use clocks so large and powerful that the work they are called upon to do is negligible in comparison with the power of the clock. All this trouble can now be banished. It is possible to make a simple and robust mechanism which will do anything in reason at any time you like to set it for.

The Time-Switch.—Before long, it should be possible to buy at a low price a clock which will switch on or off such currents as are used in everyday work at any predetermined time. Such "Time-switches" have, of course, been on the market for very many years, and have been widely used for controlling the lighting of streets, and for other purposes. On the whole, however, they have been found to be more bother than they are worth, for to be good they had to be fairly expensive. The synchronous-motor switch could be made, in large numbers of course, for a few shillings.

Automata in the Home.—We are thus led to the question of the place automata will occupy in the home of the future, assuming that such a thing as a home in the old-fashioned sense will exist at all. A few years ago, it was a favourite pastime of rich Americans to construct automatic homes. The door opens

automatically when a member of the family, but not a stranger, approaches. The door-mat automatically brushes your boots. The thermostatic oven has been switched on at the correct time in anticipation of your arrival, and a touch of a switch causes it to discharge its contents onto a table, which then travels to the dining-room. When the dinner is eaten, another switch dismisses the remains of the feast to the kitchen. The romance of science used to go on like this for pages, but I suspect that the staff of skilled mechanics and electricians necessary to keep the whole business going proved more expensive than normal service, even in America.

Nevertheless, the time-switch should find many uses in the home of the future, especially in conjunction with electric cooking and heating. It has already been found capable of heating water and making tea, and waking the sleeper when these are ready for him. Whether it would be necessary to have it go to the length of turning the bed upside down, would depend upon the sleeper.

Answering the Telephone Automatically.—Another great need for the modern home is an automatic apparatus to take telephone messages. It would be somewhat costly, but would certainly find a

large number of users, if satisfactory. It is one of those inventions which has been announced again and again, but it is to be supposed that a workable apparatus has not yet been produced, or at any rate, not put on the market. So many new developments which would seem to facilitate it have been made recently, that one may expect that a new effort will be made to achieve success. It is to be hoped that the introduction of automatic telephones will not render the application of a recorder any more difficult. One can imagine a device which would automatically raise the receiver from the hook when the bell had rung in vain a certain number of times, and apply it to the sound-recording device. The latter might well be photographic or magnetic, rather than the usual wax cylinder. A certain signal would be given to the caller, and he would then have a certain time in which to give his message; a most salutary arrangement. At the end of this time the receiver would sink back onto the hook. The sound recorder might be serviceable as a dictaphone for office use as well.

The Control of Domestic Heating.— Thermostatic control of domestic heating is long overdue. Here again the time switch could be used to cut the heating

in and out at predetermined times. This would be easiest, of course, with electric heating, but would not present any great difficulty in connection with steam or gas, if an electric supply was available to work the necessary valves.

The satisfaction of going to bed, knowing that one would be called at a precise moment to a hot bath, tea, and a warm room, would be very great. Perhaps we might feel a little doubtful about the return in the evening, for it would be annoying, if unexpectedly detained, to know that all the automatic preparations for one's return were taking place with the inevitability of Fate.

The Path of the Inventor.—With this vision of future domestic possibilities we may conclude our survey. It may have amused the reader for an hour or two; I hope it will not stimulate anyone to attempt original work. The path of the inventor is a thorny one in these latter days. It is easy to design mechanisms on paper; but it is costly to get them made at all, and very difficult and very costly to get them made properly. It is almost impossible to foresee and provide for all the troubles that may arise. The most experienced designer is sure to overlook something which, one would suppose in retrospect, should have been

obvious. The tiro at the work will make dozens of mistakes. Model after model is necessary until the troubles are eliminated. Then comes the test of time wear, and chance. It is quite possible that the first model may work perfectly, yet the design may be such that, given workmanship consistent with the possible sale price of the apparatus, a certain percentage incidence of trouble will occur. How well the motorist is aware of this fact! Even in this field, where the dimensions are such that a much higher degree of accuracy is possible at reasonable cost, the only final test of the reliability of a construction is the test of actual use over a considerable period of time. After years of work and heavy expenditure, the most promising design may have to be abandoned as hopeless.

The Patent Law.—Further, the inventor has to reckon with the patent law, which our forefathers designed for his especial encouragement. They conceived it most excellently to this end, and it served its purpose for many years. It has now been judge-made into an instrument which rarely profits anyone but patent-agents and lawyers.

The original intention was to grant a temporary monopoly to anyone who

introduced a new manufacture into the country. Unfortunately, only two cases were clearly envisaged by the law-giver. Either the person introducing the new manufacture was the "true and first inventor" of the article in question, or he discovered it abroad and introduced it into this country. In either case he was, and still is, entitled to a patent. But supposing he, knowingly or unknowingly, introduced the manufacture of an article which had been made long ago, and forgotten? At any rate in cases where the said article had never been the subject of manufacture, the original law-givers would undoubtedly, had they thought about the matter, been willing to grant a patent. The judges, however, decided that "prior publication," even in exceedingly obscure circumstances, is a bar to anyone obtaining a patent for a new manufacture.

A man may therefore invent something ("Ideas come to us, affecting the embraces of virgins, and we believe them" says Meredith), apply for and receive a patent, invest large sums in perfecting it and putting it on the market, and then be robbed of his reward because, long before he was born, someone else had the same idea, and "published" it in the technical sense. The publication may

have been, and have remained, to all intents and purposes inaccessible to the world at large; the original inventor may never have manufactured the article; he may merely have suggested that it might be done. This legal ruling is defended on the ground that it is to the general interest that all published information, apart from that in specifications of patents still in force, should be at the free disposal of the technical world. One of the motives underlying patent legislation was, indeed, to ensure the publication of matter that would otherwise be kept secret. But in very many cases, the information is made available, not by the efforts of the first long forgotten originator, but by the second unfortunate individual, the rediscoverer. As it is difficult to draw the line, it is not drawn at all. If you invent an entirely new alloy, for instance, and merely expose it to public use without saying a word about its composition, you have thrown away the chance of a patent for it.

The patent law thus becomes more and more useless, as time goes on, to the inventor.

The Future of Invention.—How far will conditions in the future favour the progress of invention? We have seen

that the patent law is failing badly in this respect. In favour of progress we have the formation of amalgamations which are able to afford large expenditure upon development work, while their monopolistic character renders them safe from serious competition when they bring out new things. The defects of the patent law thus do not affect them. Unfortunately, most of these concerns are developing into bureaucracies. Founded by engineers and scientists, their management is now almost exclusively in the hands of financiers and "business men". The whole staff, including the technical, tends more and more to assume a character indistinguishable from that of the civil and municipal services. This is hard to avoid in such large, impersonally managed concerns. When it is combined with the modern elaborate machinery for seeing that everyone attains a certain minimum of efficiency at his job, it works quite well, in all directions excepting that of technical progress. We find, however, that the so-called "research departments" (usually referred to as *re*search, no doubt by way of distinction from old-fashioned re*search*) are staffed in exactly the same way, and the staff subjected to precisely the same treatment.

But invention is a class of work totally different in nature from routine work. A good routineer ought to be an easy master of his job. It ought not to worry him out of working hours. When at work his decisions should come easily, for they should be based upon secure, tested, and accepted practice. The inventor, on the other hand, is by nature a monomaniac, a worrier—almost a case for the psychiatrist. Plenty of good inventions have, of course, been made by other types of men, but if you cut out the classical inventor type, you would cut out nine-tenths of the new and fruitful ideas. Such inventors are sometimes born so pure in type, that they will rack their brains day and night at invention no matter what circumstances they work in. Indeed, they are hardly conscious of those circumstances.

Their chance, however, of becoming members of the research staff of a large concern is small; the smaller the purer their type. Their various objectionable personal qualities prevent that. A large proportion of inventors are of mixed quality; and one has seen many deplorable cases where normal, steady salary-earners have suddenly developed an invention-psychosis. Frequently they come to a bad end, though now and then

they emerge triumphant. The incentive in almost all cases is financial gain. The technical staffs of the large concerns are, almost without exception, compelled by their employers to contract out of the benefits which the law intends to confer on the inventor, and still may confer, in spite of the judges. They have to deliver to their Company all inventions that they may make, free of charge. They are thus protected from the invention-psychosis, for if they are successful in producing something really new and valuable, they reap a very small reward; while if they fail ambitiously, there is a mark against them. Hence they are tempted to confine themselves to what appear safe lines of development. No doubt there is an enormous field for work of this class, but it is not of a revolutionary kind. Very often, also, the whole value of the safe development may be thrown away by the arrival of a new and revolutionary idea.

This method of treating the research worker in technology is folly. Each worker is an expensive item, and he either earns a great deal more than he spends, or he is a total loss. The difference may not lie in the abilities of the man, but in the intensity with which they are applied. Good research is not to

be had by buying the working hours of a man capable of it. You have to find means to make the man rack his brains day and night over his special problems. He has to create new ways and means, and creation is travail of spirit. The financial inducement is the most effective. One can see, however, other methods successfully at work here and there, for instance, an extraordinary, enthusiasm-generating personality at the head of the department. But these cases are rare.

At the present time, the *re*search departments of the great firms mostly justify the modern pronunciation. They are institutions for working over, and out, ideas derived from outside, the result of the search of others. The typical inventor still lives and works, but as soon as his products show promise, the further development is taken out of his hands. Patents are of very little use to him. He has no means of protecting himself against powerful infringers. In many cases, his pioneer patents are soon capped with detail improvements patented by the large firms. Although these may have always been perfectly obvious to him, he may still be prevented from using them, if he has failed to publish them before the enemy's patents were filed.

Decline of Commercial Competition.—A further hindrance to the progress of invention lies in the rapid decline in industrial competition. Large, well-organized industries tend to combine to stabilize their products, and avoid the expense and disturbance attending change. Further, since control has passed from the technical to the financial and business side, the financial resources available for competition are put into advertising and selling. Much more money can be made by mass-production of an article sold at a price to which the public became accustomed before mass-production began, than by continual improvement. To my certain knowledge there are gramophones and cinematograph projectors (to name only two articles) in existence which are vastly better, and not dearer to manufacture than any obtainable from the great firms to-day. But no one of these firms, by adopting an improved model, could take away business from the others to such an extent, and so rapidly, as to compensate for the increased cost due to change in design. Also, it would have at once to defend, at enormous expense, the patents under which it was working. An equal sum spent on pushing sales of existing models would bring a larger return.

Discovery and Invention.—The distinction between discovery and invention is well-known in Patent Law. It is less well-known to the public. The two are often confused. We discover the laws of nature, the facts about the world we live in. It is the task of the inventor to apply the knowledge thus gained to the solution of practical problems. If matter is the enemy, pure science discovers its habits, and invention enslaves it.

For a long time invention was well ahead of discovery. The steam-engine was invented long before the laws of thermodynamics were discovered. At the present day, discovery is far ahead of invention. The most modern and subtle of inventions, such as the triode valve or the photoelectric cell, only make use of a minute part of recent discoveries in chemistry and physics. Pure research attracts to its service an increasing proportion of the most gifted of the scientifically educated. Great endowments have made a life devoted to pure research possible and even moderately affluent. Those possessing a practical inventive gift find a full outlet for it in the problems presented by pure experimental research. Dewar invents the vacuum flask, Einthoven the string galvanometer. merely by the way, in

the course of the experimental pursuit of pure knowledge. The incentive of financial gain by monopoly is lacking, but to compensate for that, the pure research worker has the inducement of academic and public honour, a large and comparatively free life as his own master, and the satisfaction of feeling that his work is of permanent value, whereas that of the inventor may be entirely superseded and forgotten.

The Mastery of Matter.—Shall we realize the ideal of our civilization ? When we know all we can ever find out about the world around us, living and dead right down to the last detail of its atomic structure, will invention serve us to turn all this knowledge into mastery ? Will great automata feed, clothe, house, warm, light, and amuse a population from which all but the brains that can understand, and the skilled hands that can tend, have been eliminated? Will the dreams of past centuries be realized ?

The first need is enthusiasm, incentive, and material support for invention. Enthusiasm for science in general will no doubt continue, at least for several generations, but for the reasons I have indicated we may well tend to a condition of affairs when

scientists will be a kind of caste apart, pursuing knowledge for its own sake, in directions determined solely by intrinsic interest. Pure mathematics has, indeed, almost reached that stage to-day. Because all Universities are now teaching engineering, it is popularly supposed that science and practice are coming nearer together, whereas in truth all that is happening is that engineers are being trained in these institutions without a thorough scientific foundation, in the formulae of existing practice, and then sent out in the world without the equipment for applying to their practical work the discoveries of pure science.

The Humanitarian's Opportunity.—It is a curious fact that the humanitarian has hitherto done little or nothing to do away with the dreary, monotonous, and disgusting labour inseparable from industry as carried on to-day. Instead, as we saw at the outset, his efforts to alleviate the lot of the masses actually compete against the efforts of science and invention to abolish manual labour. The supersession of hand-labour is decided almost entirely on financial grounds by the management of industry, and the certainty that cheap and contented labour will always be available, calling for no capital investment, tells heavily against

the automaton. If the humanitarian really feels that the type of population resulting from his best efforts is a worthy and desirable product, there is nothing one can oppose to him that has not been said by the advocates of Mediævalism, craftsmanship, and the peasant life. But if there are humanitarians who have their doubts, one might suggest that they should seriously consider the employment of their resources on behalf of, and not against, the automaton.

Hitherto, comparatively trifling prizes have been offered, from humanitarian motives, for inventions designed to abolish particularly poisonous or dangerous occupations conducted by hand-labour. If, however, the whole weight of humanitarian influence were directed towards the substitution of automata for all forms of monotonous hand-labour, great progress might be made. The lot of the workers in the field should be made as attractive as that of the pure research worker. The idea, inevitable at a time when the problem of employment is so serious, that the first function of industry is to find employment for the masses, must be abolished in favour of the endeavour to make it supply our needs with the minimum of labour.

AUTOMATON

The supreme desire of our civilization must be realized, if its old age is to be honourable. The masses of human automata of which it makes use to-day must not be found among our descendants. Not the manual labour of teeming populations, but the power of great automata, must supply its physical needs ; and, over and above these, resources for yet undreamed-of efforts to conquer matter, space, and time.

APPENDIX

TRANSLATION [1]

Automatic Machine that will take down words from the voice.—From time to time we come across the man who has in view an automatic writing-machine that will take down words from the voice. To those who are not experts this may seem no more a product of the land of dreams than an account of the present development of radio if it had been given twenty years before the event. But the two things are not

[1] The section here translated was taken as a fair sample of *Automaton*, and sent to the Orthological Institute as an experiment, after the MS. was in the hands of the publishers. The system used was that designed by Mr. Ogden for ordinary international correspondence, commercial or epistolary. The entire vocabulary can be printed on the back of a single sheet of notepaper, and can be mastered in a few days The translation was made by Miss L. W. Lockhart, of Girton College, who is preparing a book on *Word Economy* to explain and illustrate the technique. In the opinion of the author it communicates adequately what he had said, the differences being chiefly a matter of stylistic technological associations, and would even be more satisfactory to a foreigner—to whom "Mittelpunkt" = *centre*, or "machine à écrire" = *typewriter*. The original will be found on pp. 44–50.

parallel, and it is my belief that if there is any field related to machine invention in which we shall never get results, this is certainly one. At the very start we are up against the same sort of question as in our discussion of the electric eye; that is, how an automatic machine can be made to be aware, with memory, of what is nearly but not completely the same. There is a very great difference between voices and the sounds they make for each separate word. But if there could be an electric ear which would always have the same reaction to the same sound, its reaction would still be to sound units and not to letters.

The only reaction it could have would be a sort of design for each sound; and an automatic selection would then have to be made, not from 26, but from thousands of possible sounds.

So difficult would be the invention of a process to get the letters themselves in the right order that I am of opinion that it is outside the powers of man, because it is only by knowledge of the use of the words in any given sentence that the selection of "wood" or "would" can be made by the girl at the machine as the right order of letters for that sound; she does not always do so without error now.

This question has a somewhat different aspect when taken in connection with the work which has been going on for so long, and so far without result, for the develop-

ment of an international language. But the last suggestion, of this sort seems to me to have more promise than any of the earlier ones, and through it the question of an automatic machine for taking down words from a person talking comes up again for discussion. My reference is to the plan for "Panoptic English" which has been put forward by the "Orthological Institute". It is the hope of this organization that when its present work in this direction is complete, it will be possible, by a new way of getting at the elements of the structure of language, to put into operation a system of English with a list of about 500 necessary units, by which nearly every thought can be put into words. It seems certain that the invention of an automatic machine to take down words in this language from a talker or reader who had the necessary experience, is not outside the powers of man, so long as there is no doubt as to the right interpretation of any one sound.

The record of sound by a special camera apparatus, now made use of for trade purposes in the talking motion-picture, should have a future in connection with office work. In this way a record could be made, keeping the apparatus out of sight if necessary, of important discussions or private talks between business men. Such an apparatus would make a much longer record and be easier to take about than the present machine for the same purpose, the "dictaphone". The present writing-

machine might be done away with completely if it were possible to put the records into the post without going through any other process; an early dream of the future, which was a very general one at the time of the invention of the first gramophone. In addition, it might be of great value to railways, in the making of automatic apparatus for giving directions and information about trains.

Reactions with a memory element again.—It may well be that we can get more light on some of the important questions in the science of the mind by giving special attention to reactions in which memory has a part. All that we can do here is to go with a little more detail into the discussion of that side of the question which is connected with sight and let the reader make on his own account any additions which may seem necessary. A special glass makes a picture of a form on a plain surface made up of points on which light has an effect. Can we get a system such that when some shape comes on the surface, and at no other time, the sight reaction is given? The answer is certainly "yes", if it takes up the same space and has the same position every time. Can we, in addition, give the apparatus a range of forms, so that a different sign is made for every form in the range? The answer is "yes", if the same form always has the same position on the surface. And if it does not? In that event, the automatic direction of the apparatus, for example, in such a way

that the middle point of the picture of the form is put at the middle point of the surface would not be out of the question. There would be some general effect on the apparatus, the interpretation being "figure in the field". After that it would take up a position from which the direction of its "sight" was towards the middle point of the figure. But the picture of this figure might be at a wrong angle for a memory-reaction to be made, and if that were so, the automatic machine would have to give the surface a full turn of the compass. If there was again no result it might be because the figure was greater or smaller than it should be. To put this right, it would be necessary for the machine to make a change in the amount of space taken by the picture, by a changing of the position of the parts of the apparatus in very small steps, and by taking observations of the results of each step all round the compass. It would, no doubt, take many years of work and a great amount of money to make a working apparatus of this sort, but it would be possible.

But when we come to the question of memory-reactions by an automatic machine to a number of forms which are like but not the same, the only suggestion that comes to mind is one which would make the range of the automatic machine greater by the addition of a number of separate forms, each of which is always the same. But one can be nearly certain that this is not the

natural way. The processes of the mind are no doubt dependent on some system of "go and not-go"[1] for forms of all dimensions within a certain range. The same form gives the same reaction, though different in detail, till there has been a change in different directions up to a certain point. But in the process, the form seems in some way to be taken out of the three dimensions of space. A picture in the looking-glass of a form which is different in all three dimensions of space is at once taken to be the same, or nearly the same, as the figure itself.

Colour.—Colour is a completely different question. Here it is easy to get a memory-reaction by the use of an apparatus that makes a reaction to light, because the selection of a ray of any colour can be made from light by a piece of glass of a given colour, and taken by itself. If there is need of a more delicate apparatus, use might be made of a special glass by which each colour in the light gets bent differently. The uses to which this invention can be put in industry will be many. For all operations in which colour gives direction to the hand, the automatic machine might take the place of man. Where the selection of natural things like minerals, fruits, eggs, and so on is now made by hand or they are ranged with reference to colour, the work is certain to be given to machines in the future. Attention has already been given

[1] In use in Woolwich Arsenal for a "limit gauge".

by the newspapers to an automatic apparatus for putting on one side Havanas and such-like of a bad colour. The control of chemical processes is often dependent on observations of qualities having some connection to light, such, for example, as the colour of substances, and how dense they are. All these controls could well be made automatic.

Colour as a sign for automatic interpretation.—There is no doubt that colour might be of great value if put to special uses in the division of objects of different sorts which are to go through an automatic process. A division of cards by their colours could readily be made, and with a little adaptation the same thing could be done in automatic systems for accounts and so on, in place of the present system of holes in the cards. A letter-cover of given dimensions with a number of colour-designs would be an important feature of an automatic system of getting letters into the right classes in the Post Office.

It is probable that there will be an automatic way of putting on the right stamps as a part of the more efficient letter-organization of the future. This might be done by putting money into a machine; or, in business houses, by the use of an apparatus that is now to be had. There would be an automatic sorting of the letters in their colours; it being, naturally, the business of every person to make use of a letter-cover of the correct colour for the place to which it was going. The old way of doing things could go on side by side

with the new, if a special payment gave one the right to make use of a letter-cover not of the Post Office design.

This electric apparatus could equally well be made to have reactions to designs in black print on a white envelope, each different town or place having its design.

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